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ABSTRACT

Part of the Concepts in Science Project at the University of Surrey is to explore the complex structure and organization of ideas and meaning that children bring with them to their science lessons. To examine these ideas and meanings, a distinction is made between children's intuitive understanding of their world (children's science) and the conceptual understanding of physics held by the science teacher (scientist's science). The scientific concept of force is then used to further illustrate (by means of interviews with children) the distinction between these two views, and the misunderstanding that can occur when the two forms of science fail to encompass each other. One feature of children's science identified is the tendency to endow inanimate objects with a will or purpose, a process described by Piaget as "animistic thinking." It is suggested that animism is incompatible with traditional scientific objectivity unless both points of view are considered from a constructive alternativist philosophy. It is further suggested that children are more concerned with construing situations and events and that, in their flow of language, they fail to limit the implications of their words or appreciate the metaphors of physics. (JN)

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A CONSTRUCTIVE ALTERNATIVIST VIEW OF CHILDREN'S SCIENCE

Paper to be presented at the 4th International Congress in Personal Construct Psychology, Brock University St. Catherines, Canada, August, 1981

BY

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From: Encyclopedia of Psychology

(Ed. Eysenck H.J., Arnold W.J., Meili R.:

Fontana/Collins 1975)

Anthropomorphism. The tendency to interpret the manifestations of the animate and inanimate environment analogously to human behavior and experience. Anthropomorphism is not only a feature of mythic thinking (see Myth), but in the history of science played a part in animal psychology, and was only overcome by the proficient methodology of comparative psychology (q.v.) and behaviorism(q.v.).

W.Sc.

Animism. The view that ascribes anthropomorphic behavior (see Anthropomorphism) to objects and natural phenomena: i.e. the attribution to inanimate objects of such conditions of human activity as life, thought, free decision, by projecting them outward from the human state. Piaget has described an animistic phase in the development of human intelligence. In E.B. Taylor's anthropological studies of religion, animism in so-called primitive societies is seen as a form of "understanding of the supernatural".

A.T.

Abstract

I have drawn a distinction between children's intuitive understanding of their world (children's science), and the conceptual understanding of physics held by the science teacher (scientist's science). To exemplify this distinction I have chosen the concept of force and described it from both points of view. One feature of children's science is the tendency to endow inanimate objects with a will or purpose. This was a process described by Piaget, which he called 'animistic thinking'. Animism is incompatible with traditional scientific 'objectivity', unless both points of view are considered from a 'constructive alternativist' philosophy.

INTRODUCTION

Interviewer: Suppose a friend had missed a lesson and came to you to ask "what is force?" - what would you tell her?

Susan, 13 yrs, explaining: .....well....I'd say that forces are to do with people.... it's in their arms and legs when they push and pull things ....in their muscles

This is an extract from an interview between myself and Susan, concerning her meaning for the word force. During the interview we play the game of explaining things to a mythical friend, a procedure Kelly called 'using the invitational mood'. He suggested in a paper called 'The Language of Hypothesis' (1969) that this manoeuvre allows for a wide range of constructions, and that:

> "there is something in stating a new outlook in the form of a hypothesis that leaves the person intact and whole".

The interview example above, comes from a series of interviews from within the Concepts in Science Project at the University of Surrey. Part of the project is to explore the complex structure and organisation of ideas and meaning that children bring with them to science lessons. The project moves from the view that successful science teaching requires an appreciation not only of the scientist's view of the world, but also an appreciation of the language, beliefs and the expectations which children bring "whole and intact" to science lessons. In this paper I am using the expression "children's science" to represent these beliefs and meanings for words; an expression taken from the work of Gilbert, Osborne and Fensham (1981). In a sense it contrasts with "Scientist's Science", a term that implies a meaning for a word held by a consensus of the scientific community.

One can draw a distinction, too, between 'scientist's science' and 'teacher's science', but for the sake of the argument I'm putting forward here I have included both under the term 'scientist's science'.

Many research studies in recent years have shown clearly that children develop their scientific world view to enable them to predict future events (for example, Driver and Easley 1978). There is growing evidence (Clement 1977, Nussbaum and Novak 1976, Le Boutet-Barrell 1976, Stead and Osborne 1980) to show that children's science is both tenacious and durable, often impervious to traditional classroom science teaching (Viennot 1979). Such views of the world, beliefs, and meanings for words, are not simply isolated ideas (Champagne, etal 1979) but rather they are part of the complex conceptual structures which provide a sensible and coherent understanding of the world from the child's point of view.

The underlying assumption to this description of children's science is that it has both important epistemological value and high educational status. This is not an assumption most obviously shared by those who uphold the traditions of science education (see Barnes 1971, Donaldson 1978). Too often there is an assumption that children's beliefs must be directly and efficiently overcome by the strength and logic of 'true' science. When noticed, children's constructs are not to be built and developed, but 'corrected'. To place a high value on a personal construction of learning is to adopt the kind of relativistic view of knowledge discussed by Pope (1980, 1981). She suggests that a relativistic epistemology is compatible with Kelly's viewpoint and says:

> "This emphasis on the person as the meaning maker is central to Kelly's position". (1980)

Kelly himself describes the philosophical assumptions of constructive alternativism by saying:

> "Like other theories, the psychology of personal constructs is the implementation of a philosophical assumption. In this case the assumption is that whatever nature may be, or howsoever the quest for truth will turn out in the end, the events we face today are subject to as great a variety of constructions

as our wits will enable us to contrive". (1970)

These are important points, and are ones I will return to later. At this point I want to describe an approach to understanding some of the meanings that children hold in their view of the world.

Gaining access to Children's Science: the Interview-about-Instances Approach

Driver and Easley (1978) refer to children's science as 'alternative interpretations' and suggest that:

> "In learning about the physical world, alternative interpretations seem to be the product of pupils' imaginative efforts to explain events and abstract commonalities they see between them".

The elicitation and elucidation of the characteristic features of children's science call for a method that is responsive to the pupils involved. It would need to recognise the individuality of the person whilst allowing for a systematic attempt to explore that individuality and, as suggested above, to leave it 'whole and intact'. From this basis I have adopted an approach called the Interview-about-Instances technique (IAI) introduced by Gilbert and Osborne (1980).

In outline, the IAI method consists of tape-recorded dyadic discussions with a pupil, using a series of pictures as a focus. These are drawings concerned with the essence and application of a central concept within physics. Each picture card depicts a line drawing of a situation which may, or may not, represent an example of the concept as seen from the orthodox physics view. The method elicits a wide range of responses, and in each case the pupils are asked for explanations, their own examples and meanings for words. Wherever possible, it is the words the children use to describe their concept that are then used by the interviewer to explore the ideas further.

In general a deck of pictures may consist of an equal number of examples and non-examples. Some of these would lie on the 'borderline' of the concept, being unusual, or unorthodox applications of the concept. Many of the pictures would contain a 'dynamic element' that require the pupil to make some predictions as to the outcome. Their predictions and explicit explanations endorse their tacit understandings and constructions of the situations.

Frequently children evolve two or more hypotheses, or working 'models' of the conceptual framework surrounding the cards, during the course of an interview. Their models may be conflicting or complementary, as seen by ther interviewer, and may be presented during the session as a working hypotheses.

The child-the-scientist, would seem to evolve a set of constructions which he/she tests out, and may discard in favour of a new set of constructions if the former fail to adequately anticipate events.

The IAI method can be seen to lie within the research framework of 'case studies'. The interviews are best conducted in private, for only then can one hope for both participants to relax. Early use of open-ended questions allows the session to develop into a discussion where meanings are negotiated, and where evaluation and critical comment are avoided. The recordings are transcribed and annotated to be as faithful as possible to the exchanges. Each transcript is analysed and interpreted on the basis of the context of each utterance. As I have already mentioned, our method and approach accords a status and importance to the child's own view. My stress is compatible with that of Kelly's who saw the role of the teacher as helping:

> "to design and implement each child's own undertakings.... To be a fully accredited participant in the experimental enterprise she must gain some sense of what is being seen through the child's eyes." (1970b)

Sadly, see Barnes (1974), Donaldson (1978), Martin et.al. (1976) Holt (1966), this is seldom the case in school science. Barnes, for example, describes a science lesson where a teacher is discussing a sample of milk. The teacher perceives it as an exemplar of the category 'suspension'; a distinction he fails to make clear to his

pupils. Barnes says:

> "Far from helping them to bridge the gulf between his frame of reference and theirs, the teacher's language acts as a barrier, of which he seems quite unaware. They are left with their own first-hand experience - 'it smells like cheese'. The state of the other less articulate members of the class can only be guessed at. The teacher, frightened by his sudden glimpse of the gulf between them, hastily continues with the lesson he has planned."

To highlight this distinction between children's science and scientist's science I have chosen a major concept within school physics: the concept of force. I will deal first with its 'physics' meaning, and then follow this with an example of just one of the may constructions that children put on the word.

The Concept of Force

The concept of force is one that reaches through the very centre of orthodox physics. At school level it permeates the curriculum, and is used as a 'basic concept' - a necessary prerequisite for the understanding of phyiscs. Classical mechanics is built upon Newton's concept of force. 'Electricity' and 'magnetism' are combined within electromagnetic forces, whilst 'modern' physics concerns forces at the microscopic, atomic, level. And everywhere there is ubiquitous gravity.

The physics view (the scientists' science view) of force bears little resemblence to the muscle-bound push or pull of everyday life. It is not something that causes motion, it is simply a something (whatever) that changes motion. To the ancient Greeks of Aristotle's day the state of rest was a 'natural' state and needed no explanation. To the Newtonian physicist, there are two states that are 'natural' and need no explanation: the state of rest and that of constant velocity. Any object or influence that changes either state does need explanation, and is named a resultant force. In other words, resultant force is a name for the interaction that occurs whereby a body changes its velocity.

This part of the concept force, then, is at variance with the physical realisation of pushing, say, a car along a horizontal road. This afferent, innervative sensation requires a constant force to be applied to the car to keep it moving and means that the pusher tires as his/her strength eventually fades.

These two views of force, the Newtonian and the commonworld, are not the only two possible interpretations of the word. A person 'forced to agree' with another, or 'forced to do' what another wishes, is under some strenuous obligation to comply, within a societal framework. We also have expressions like 'the armed forces', 'the police force', where the suggestion of social coercion grows stronger. The activities of large groups of people can be referred to as 'the labour force', or the force of 'public opinion' etcetera.

Within the precise language of physics these interpretations are discounted. The physics concept of force can be ascribed a number of criterial (essential) attributes and embedded within a restricted context characterised by non-criterial (non-essential, but important) attributes. The concept can be dissected in a systematic way (Watts 1980a,b) and laid open to inspection. In its turn, the pupils alternative constructions can also be examined, both during the interview and after. In the course of the discussions they may be asked to play the 'game' that introduced the paper, of explaining to a hypothetical friend their meaning of the word force. The youngsters may be asked for their own examples, or their constructions of events, of the situations emphasised in the pictures. During the analysis, I can comment about the generality and popularity of constructions. Moreover, I can explore the attributes that the youngsters ascribe to their meaning of the concept force, and explore the role it plays in their world view.

A commonly recurring feature of their construction of events is an animistic or anthropomorphic viewpoint. More than fifty years ago, Piaget (1929) described children's animistic thinking in some detail. To Piaget, animistic thinking refers to the tendency for children to ascribe life to inanimate objects. Anthropomorphism refers to a tendency to ascribe not only life but also human characteristics to objects. In this paper I am using this particular feature to emphasise the gulf between the subjective personal constructions of the child and the objective 'truth' of the traditional science taught in schools. The animistic flavour of the child's accounts are in strong contrast to the neutral language of science. As an example, Susan (13 yrs) and I discuss a picture of an astronaut, outside his space ship, deep in space. She says:

(I means Interviewer)

432 S having never been I don't really know (laughs) so . um . if he was near something I would have said that it would have . pulled it towards it . pulled him towards it

433 I it not being . I mean . . being near the rocket itself isn't enough then ? or or . wouldn't the rocket just sort of pull it towards it?

434 S no I don't think the rocket would

435 I what is . what sort of thing would pull him then I mean what are you thinking about?

436 S . in a way something that's . alive really . I mean I don't mean you know live . live . but that (ship) to me is . is dead

437 I alright

438 S it's nothing it doesn't eat sleep drink breathe

439 I right

440 S anything

441 I okay

442 S but a planet to me does

443 I okay .

444 S I mean .

445 I and and that would sort of ...?

446 S pull it

447 I pull it . pull on it ..?

448 S in a way yes

11

(the numbers on the left refer to each person's utterance, the dots indicate pauses)

A Theory of Animistic Thought in Children

In "The Child's Conception of the World" (1929) Piaget wrote about the animistic and anthropomorphic patterns he saw in children's descriptions of the world. In "The Child's Conception of Physical Causality" (1930) he dealt at length with their conceptions of force and says:

> "The child fills the world with spontaneous movement and living 'forces'; the heavenly bodies may rest or move as they please, clouds make wind by themselves, waves 'raise' themselves, trees swing their branches spontaneously to make a breeze, water flows in virtue of a force residing within it"

He suggests that children see movement as caused by 'forces', and 'forces' in turn explained by a bipolarity between internal and external 'motors'. All movement would seem to have both a cause and an aim; an external influence and an internal purpose. He says:

> "in a word, child dynamism is a sort of panpsychism or hylozoism".

Piaget describes further the kinds of responses children give when asked which particular objects have force. Water is 'strong', particularly when a current is running, whereas clouds are not strong, since it is the wind that moves them. The children categorise each object by their force if 'they are useful', 'can do things', 'because they burn' or 'gives light'. The following extract is taken from his interview with an 8½ year old:

> OL (8½): "Has the moon got force? - No, because that's the way she moves: it's the air that makes her move. - What does it mean to have force? - It's something you have in your body."

Piaget summarises the interviews by saying:

> "These children define force exactly as they define life. According to a third type of answer, which is by far the most common, force is defined as activity in general and useful activity in particular. These answers recall very closely those of the first stage of animism." (1930)

The responses that Piaget reported then are remarkably similar to those reported in current owrks (Stead 1980, Osborne 1980, Watts 1980). Compare the responses above to those taken from recent interviews between myself and youngsters of ages from 12 years to 18 years. Their answers are in responses to the drawings shown in figure 1.

A Space Rocket at Take-off

Simone (S) 16 years, expecting to get a good exam grade in physics:

(I = interviewer; the numbers in the lefthand column refer to each discrete utterance).

268 S the spaceship's got a lot of force because it's pulling itself up .

269 I uhum

270 S and then when it's in space it might drop a bit off . that bit or that . and you're left with that little bit that's got a smaller engine . that sort of just hovers about

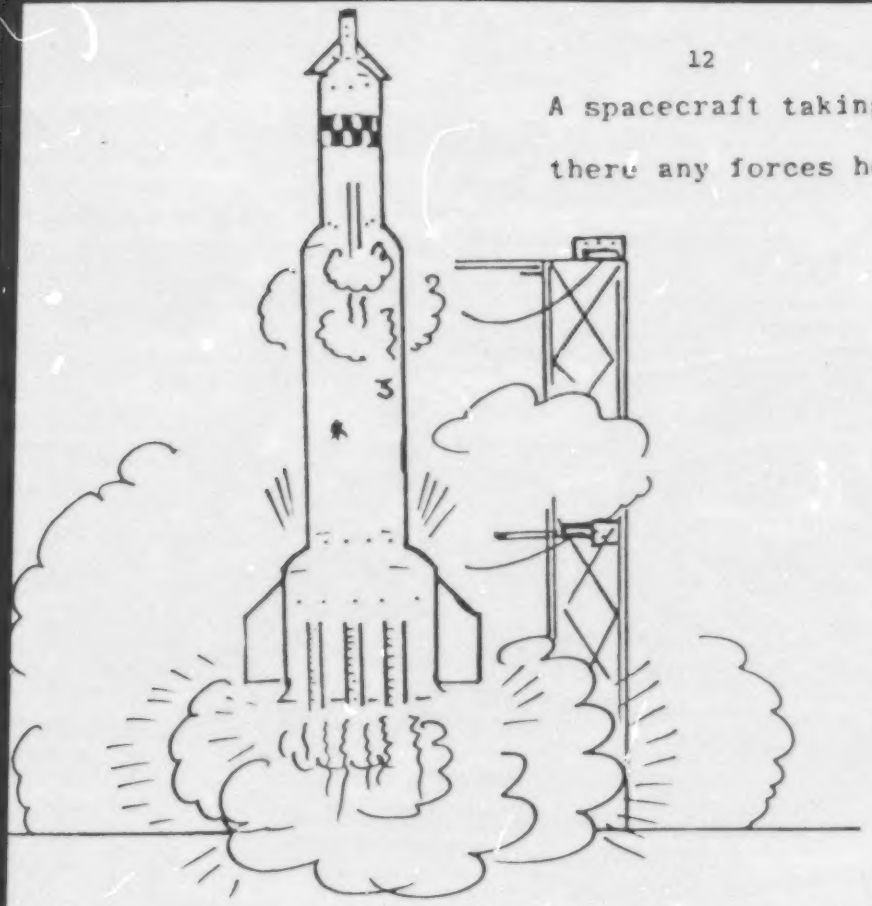
271 I mmm mmm

272 S until it lands

TED (T) 12 yrs:

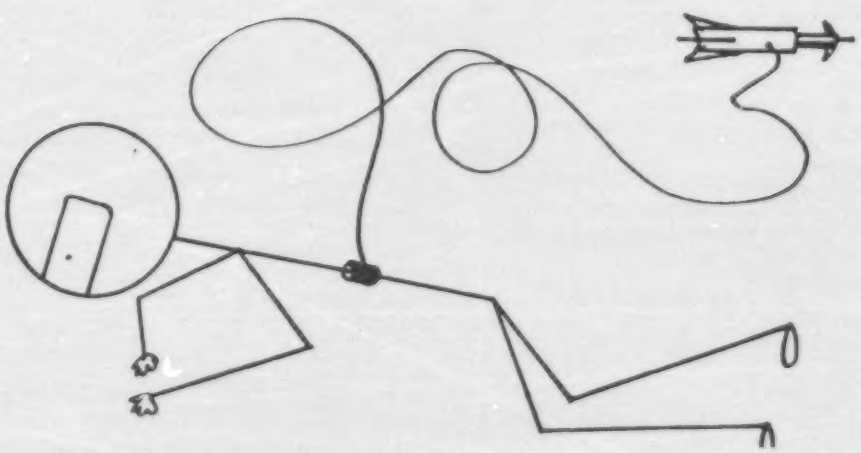
270 T it needs a big force because the gravity would either pull it down . when the rocket was still . and no energy to . gravity kept it down . but now it's got a lot of . of . energy . to push . push . pressurises the umh . ground down . and helps itself itself to move up . there's just nowhere else for it else to go

A spacecraft taking off. Are there any forces here?



Walking along with a balloon.

Are there any forces here?



An astronaut floating in space. Are there any forces here?

Figure 1

KEVIN (K) 13 yrs:-

10 I okay . what about something like a space craft taking off

11 K . forces of gravity it's defying gravity pushing up against gravity . you know gravity is trying to pull it down

A Person Holding a Balloon

SALLY (S) 12 yrs:

142 S umh . yes there's force there . the force of his legs . and his arms holding the balloon and that . . it it's er umh . helium balloon . it's pulling itself up and so he's got to pull it down . . there's force in the balloon . . especially if it's a helium one because . . they rise . the other balloons just sort of . . rise and then they come down . so there's a force in the balloon and his legs maybe his head . if he's moving it . . but the most force there is in his legs and the balloon . . maybe his hand and in his arms . .

RICHARD (R) 14 yrs

200 I ..... what about that one any forces there?

201 R . . . say there's um . a force in the balloon from the . air that you've put in there to stay up

202 I uhum

203 R . . 'cos the . air in the balloon is keeping the balloon up it's going up to . escape and go up so the balloon's going up

Here we see constructions very similar to those extended by Piaget's children, albeit considering very different situations. Children describe the rocket as "pulling itself up", "it helps itself to move up" and of it's "defying gravity". The balloon is possessed of forces that make the balloon "pull itself up" and "try to escape".

For Piaget, animistic thought is part of the transition from subjective thought to objectivity. He postulates a series of 'equilibriations' whereby the child's intellectual structues are reconstructed at each 'stage'; 'egocentrism' giving way to objectivity by successive 'decentrations'. Egocentrism is not selfishness or inconsiderateness, but simply an inability to take another person's point of view. He says:

> "This, then, is the sense in which we can speak of precausality: indifferentiation between physical causality and psychological or logical motivation. What are the roots of this precausality, whose dual fruit is childish animism and artificialism? Once again, we believe the answer to be: egocentrism and the resultant intellectual realism which it brings in its wake.
>
> Ego-centrism helps, as we saw, to make the child unconscious of himself. But this unconsciousness goes far beyond the difficulties in introspection which we described; it goes so far as to prevent the child under 7-8 from being aware of the phenomenon of thought as a subjective phenomenon, and even to prevent him from establishing the exact limit between him own ego and the external world." (1951)

The children confuse their own selves and the outside world. They regard their own point of view as abosolute and in the centre of the world. Because they are egocentric and alive they believe in an animistic world in which rational phenomean are seen as anthropomorphic. The transition of thought from subjectivity to objectivity is also the transition from the 'primitive' belief, that all objects are conscious, to the notion that only humans and other animals are conscious. Piaget describes the growth of objectivity as a "kind of Copernican revolution" (1930) whereby the child's knowledge is progressively decentered. And therein lies the conflict. To Piaget, the eventual progression through the stages is a 'growth' away form subjectivity. To Kelly, the construction of reality is highly subjective at whatever stage, and is open to "as great a variety of construcitons as our wits would enable us to contrive."

An Alternative View of Animism

It is to Piaget that we owe the description of an animistic phase in the development of human intelligence. And yet I have tried to show that his is an unsatisfactory description, based as it is on his notion of egocentric and decentric thought. These are concepts that have been criticised by Donaldson (1978) Brown and Desforges (1979), amongst others. To a 'constructive alternativist' view, animism would be just one of a variety of ways of describing nature and natural phenomena. According to Kelly, each person erects for himself or herself a representational model of the world which enables them to chart a course of behaviour in relation to it.

> "Constructive alternativism holds that man understands himself, his surroundings and his potentialities by devising constructions to place upon them and then testing the tentative utility of these constructions against such ad interim criteria as the successful precition and control of events" (Kelly 1966)

It may be that the child considers that a space rocket or a balloon really is alive and "trying to escape gravity". It would be a model that would await confirmation or refuation as experience grew and the utility of the model could be measured.

It is also entirely possible that the child's concept of 'alive' is at variance both with the adult's or, more particularly, with the science teacher's. Evidence (Stead 1980) would suggest that children have a concept of 'living'that encompasses a wide range of situations otherwise described as inanimate. Instead of confusing ego with the outside world, the child is using language instrumentally. Donaldson (1978) suggest that the child's awareness of what he/she talks about normally takes precedence over his/her awareness of what he/she talks with. She says:

> "in the early stages, before the child has developed a full awareness of language, language is embedded for him in the flow of events which accompany it. As long as this is the case, the child does not interpret words in isolation - he interprets situations."

Nor is it surprising that children should adopt terms that have overtones of animism when heard by a scientist. The very language of physics, for all precision and explicitness abounds with terms that are ambiguous to the unwary. Light source interferes with light source, electrons become excited, poor electrical conductors resist and so on. Even when the words like work, power and force are stressed for their special sense in physics (not always the case, by any means) we are still left with verbs like act and exert. Inanimate objects exert forces on each other, and as Helm (1980) says:

> "This verb unavoidably conjures up an image of muscular effort. Thus the student asked to name the agent exerting a particular force and not trained to proceed with caution might easily go off in search for the muscular, or pseudo-muscular 'origin' of this force. After all, when a force is a 'push' or a 'pull' what more natural than to look for the ultimate pusher or puller."

What seems clear is that the physicist draws analogies between the kinds of influences that objects have upon each other during an interaction, and the muscular activities of humans. This type of analogy Schon (1979) calls a 'generative metaphor'. He says:

> "In this tradition, metaphorical utterances - "Man is a Wolf" along with the rest of the rather dreary repertoire of hallowed examples - are significant only as symptoms of a particular kind of SEEING-AS, the 'meta-pherein' or 'carrying over' of frames or perspectives from one domain of experience to another."

In this sense, a generative metaphor is a way of seeing, and of generating new perceptions, explanations and inventions. The physicist uses the terms force and living metaphorically by carrying over their meaning from the frame of human activity to that of the realm of physics. For instance, one might talk of the 'life of a battery', the 'live' terminal of an electrical supply, the 'half-life' of a radioactive material, or the 'life-time' of our sun. It is not difficult to see how the notion of a 'mother earth' or 'mother nature' gives way to the 'life-cycle' or 'death' of a star. Within this argument Sally, page 13,- who described the earth as being alive - might be seen as carrying-over her concept of living in order to describe the situation in the picture: the planet exerting a gravitational influence on the astronaut.

From this description of a 'metaphorical language' of physics, three major points seem obvious. Firstly, there is a need to make science educators aware of the generative metaphors that underlie their own disciplines. This is not as easy as it may sound, since such metaphors are ordinarily tacit. A considerable amount of research and reflective thought may be required to 'unearth' the metaphors that shape the perceptions and understandings of physics.

Secondly, attention must be focussed on the language of physics to distinguish between the terms used, and the processes involved in any situation. Physics teachers may have lived with their chosen subject so long that it's technical terms and it's way of speaking are all so well known and fluently used that they seem to be second nature. There is no reason to suppose that pupils will somehow tacilty understand the simularities and analogies of phenomena construed by the practised physicist.

Lastly, considerations must, of course, continue to be made of the child's own view of the world. That is, we must attmept to explicate the interaction between 'scientist's science' and children's constructions of their own experiences.

Summary

In this paper I have not attempted a comprehensive outline of either the theories of children's conceptual development, or of Kelly's philosophical arguments. Instead I have focussed on a number of issues that I feel highlight the points I wish to make. I hope to have encouraged an important distinciton between children's scientific ideas and those of their teachers. I have pointed to the 'gulf of understanding' that occurs when thse two forms of science fail to encompass each other. I have chosen an example from within our current research project, and describe both points of view in relation to the concept of force. I have looked at Piagetian theory, which described one feature of children's conception of force as animistic. Finally I have suggested that perhaps children are more concerned with construing situations and events, and that in their flow of language they fail to limit the implications of their words, or appreciate the metaphors of physics.

Throughout, I have adopted an assumption that a person contructs reality in their own terms, and that their construction is of value within a programme of learning. I have typified the traditional science teacher (a little unfairly) as bound to the search for objective truth and 'correct' science. I leave the last word to Kelly who suggests:-

> "No wonder, then, that, in the eyes of such a conservatively minded person, our assumption that all facts are subject - are wholly subject - to alternative constructions looms up as culpably subjective and dangerously subversive to the scientific establishment." (1970)

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